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Notes on Solar Observations at Stonyhurst College Observatory.

By the Rev. W. Sidgreaves.

Drawings of Sun-spots and Faculæ.—In the summer of 1891 an arrangement was made for a tentative examination of the collection of drawings of Sun-spots and faculæ; with the object, primarily, of ascertaining whether it could be considered probable that any trustworthy improvement might be made upon Carrington's measures of solar rotation; and, secondarily, of estimating by the experience of one year the labour of dealing with the work of a dozen.

For this purpose the period of least spot frequency—the year 1889—was selected, as offering a field of inquiry comparatively free from the entanglement of old with new growths. It was hoped that a careful study of the behaviour of the several groups both of spots and of faculæ during their lifetimes might lead to some systematic selection of least wandering landmarks that would be independent of that personal estimation of their stability necessarily employed by Mr. Carrington.

The reductions have been executed with extreme care by Mr. W. McKeon, to whom we are indebted also for nearly all the drawings made during the lifetime of the late Father Perry. The work was finished, after numerous interruptions, at the end of 1893. It contains complete tabulations of the heliographic positions of spots and faculæ, and of their deduced diurnal motions, seventeen charts of mean positions (including the winter months of the preceding year), four charts of daily positions, two charts of distribution in latitude, and one of "recurrences."

The heliographic positions have been read off the drawings by means of a transparent disc projection of the hemispherical lines of latitude and longitude, which has been carefully tested by comparison with the recorded positions of spots in the Greenwich Catalogues, and has been found to give the Greenwich measures within 0°·01 of longitude and 0°·10 of latitude.

The table of diurnal motions shows that the erratic movements of spots, even after the first commotions of formation have subsided, are so great that only a very long series of observations could be trusted for an amendment to the adopted period of the solar rotation. The slower rotation in higher latitudes, first noted by Scheiner in 1630, is clearly indicated; but Carrington's law of this variation is hardly perceptible. Carrington also drew attention to the recurrence of spots in the same position. This tendency has been since observed by Secchi, Perry, and Maunder,* and we find it well marked in the year 1889. The chart of recurrences shows eight distinct regions where spots have reappeared after extinction, but we find no indication of per-

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* *Le Soleil*, tome i. p. 142; *Astron. Register*, 1884 November, p. 252; *Monthly Notices of R.A.S.*, vol. l. p. 362.

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manency in these regions—nothing to mark an area on the solar map as an irruptive region corresponding to our volcanic countries on Earth. They are, however, indicative of a more enduring state of disturbance than is measured by the lifetime of a single spot, for it is not improbable that a recurrence springs from the same source as its predecessor. And if this be true, the spots must be more subject to drift than their underlying origins, for nearly always the recurring spot is found to the rear of the former position.

The brighter patches of matter, known technically as faculæ, have been the more carefully studied since they were not included by Carrington in the work imposed upon himself. They have been treated in every way according to his method of estimating the motions of spots. Their greater extent of surface and their greater length of duration add much to the difficulty of identification at their several reappearances with the solar rotation. This is possible and comparatively easy at the minimum period; but at times of greater solar activity the several groups of faculæ would become too entangled for separate treatment. On this account it would seem a hopeless task to measure the solar rotation by the motion of faculous groups at any other than the minimum period; and no attempt has been made to carry on the work beyond the year 1889, although the results of this year show favourably in comparison with those obtained from the spots, and prove that the uncertain fixity of an adopted centre of a group is more than compensated by its much longer span of life. The average duration of a group of faculæ in 1889 was five times that of the companion spot.

The tabulated heliographic positions of the faculæ show that these are roughly subject to the same law of rotation-change as the spots. But the question of "lagging" seems to be left open. The appearances on the charts of faculæ and spots are decidedly in favour of the faculæ falling behind the spots in their march across the solar disc. Mr. McKeon, who has had the advantage of continous observation of the solar surface while sketching the spots and faculæ, is of opinion that there is no real change in the relative positions of the two: that the appearance is only the result of the previous extinction of the following member of a double spot, which has left its retinue of faculæ as attendants on the surviving and leading spot. In this way the survivor is left well to the front of a large group of faculæ, with the appearance of heading its way out of their midst. There can be no doubt that this history of the group robs the picture of the major part of the first-sight impression of lagging faculæ; but when all allowance has been made for the extra appendages to the surviving spot, there is—to the writer, at least—some evidence in favour of a real falling back of the group of faculæ. But it is not clear whether this has been a gradual retardation, or whether it is to be attributed wholly to the leap forward of the leader, so often observed in the first days of a twin spot group.

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The following table will serve to show the degree of probability we have for asserting that faculæ in general drift with the spots. Of the thirteen groups observed in the period, two were found in North Latitude at 5° and 7°, and all the rest appeared south of the Equator—viz. one at 2°, one at 3°, four at 8°, three at 9°, and two near 25°.

Mean Latitude.	No. of Groups.	Extreme Difference of Diurnal Motion.	Mean Diurnal Motion.	Carrington's No. for Spot Motion.
°		′	′	′
− 3	2	8	+15	+13
+ 6	2	8	+11	+11
− 9	7	32	+19	+ 8
−25	2	5	−13	−23

There is a very marked difference of motion indicated for the higher latitude; and it is sufficiently in accord with Carrington's law for the spots to warrant the conclusion that a great number of observations would establish, in general, the same law for both faculæ and spots. An extensive investigation of this nature might also result in a differential law for the two motions; for it cannot escape notice that the table shows nearly uniformly an accelerated drift of the faculæ as compared with Carrington's numbers obtained from the motions of spots.

The outline history of a group of spots and faculæ, as learned from the study of twenty-seven groups of 1889, may be given in a few words. First a few bright faculæ appear; in a day or two one or more black dots are seen in their midst; these rapidly increase along with the faculæ, and attain their full growth in about five or six days, while the faculæ continue to grow with the waning of the spot till they attain their fullest development at the extinction of the spot. At this epoch they begin to extend over a large area, steadily losing their lustre and falling off piece by piece, notwithstanding the frequent rekindlings amongst them by small newly-formed spots.

Of the parts of the outline history of a spot, the circumstances attending its birth are, no doubt, of the first interest in the connection of facts with theoretical explanation. The prior appearance of faculæ has been already noted in a communication to the *Monthly Notices* of 1891 December, where a full account was given of the nature of the evidence afforded by our drawings at this minimum period of solar activity. Further evidence was discovered later, and mentioned in the Report of the Council in 1893 February. And since then three other spots have been added to the list, making a total of nine observations of spots preceded by small bright faculæ. For six of these the evidence of precedence is complete, and for the remaining three only wanting as to the certainty of the complete extinction of the faded remains of a former group.

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In the same report of 1893 February it was noted that two remarkable polar belts of small short-lived faculæ, unassociated with spots, appeared on the charts in latitudes 72° north and south. These deserve the additional remark of the observer that they were too clear to escape notice, although of less intensity than those of the lower belts, and left no doubt upon his mind of their reality. The extensive regions of faculous matter shown on the photographs at Paris and Chicago have led us to doubt whether the photographic charts will agree with our drawings in this respect. But we think that the marked way in which these little patches have caught the eye must claim for the high-latitude zones a distinctive character at the minimum period.

Photographic Plates of the Spectra of Sun-spots and Faculæ.—Our method of photographing the spectra of spots has been described in the *Monthly Notices* of 1893 February. We found after some experience with the enlarging lens mentioned in the same paper that the amount of light supplied by the double reflection from the two small mirrors of the heliostat was not enough for the enlarged image of a spot. The exposure became too long, and it was practically impossible to keep the spot sufficiently stationary on the slit for a satisfactory photograph. Our collection, therefore, of photographic plates of the spectra of sun-spots and faculæ has the disadvantage of showing only a very small band for examination; and we give the results rather as suggestions seeking correction or confirmation from better instruments than as facts established by our observations.

1°. Our plates of the yellow and green regions afford no trustworthy evidence of absorption lines widening over spots. There is, no doubt, an appearance of widening where the spot band crosses the spectrum, both on these plates and on those exposed to the violet rays; and this appearance is more striking on some contact positives than on the original negatives. But the appearances all but fail under the test of micrometer readings: the most that could be made of the strongest examples, with all bias in favour of the widening, was about $\frac{1}{100}$th of a millimetre, and from this we have to deduct something for the photographic widening, which, as pointed out by our President on a former occasion, is due to the feebler light of the spot, which is equivalent to a shorter exposure. An attempt was made to measure the amount of this deduction on some imitation spot bands obtained as described in our report in the last February number of the *Monthly Notices.* But the only conclusion we could formulate was that no certain difference of measurement could be made out, although the appearance of widening was more pronounced on the real spot bands than on their imitations.

The denser spots appear to stop out the photospheric radiation almost completely. On some plates exposed to one of the very dark spots crossing the solar disc in the first week of 1893 September, which bear the evidence of a steady image

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during the exposures, the absorption lines can be seen crossing the spot band, but only with the aid of a slotted screen to stop out the rest of the picture; and on these we can find no appearance of widening.

2°. The double reversals of the calcium lines at H and K are greatly weakened over spots. This is so remarkable that it has appeared probable that over a full-grown spot there is no reversal of these lines, and that what is seen on some of the plates is only the effect of tremor of the image, on account of which a neighbouring bright facula often occupies its place on the slit and leaves its impression on the plate. On several plates which bear the marks of an unusually steady image, and which show a dense spot, the faculous reversals are nearly cut out by the spot band.

3°. In the immediate neighbourhood of a spot the bright reversals, if double at all, are usually only very feebly so, the central absorption being almost completely wanting, and the radiations thick and strong and closing up.

4°. At a distance from the spot the doubling of the reversal is more pronounced, and the bright components are thinner.

5°. There are traces on some plates of a continuous spectrum from the faculous matter, and occasionally this continuity is more marked through a range of a few tenth-metres on either side of H and K than elsewhere.

So far as these observations may be considered facts, they seem to be confirmations of the action in spot formation as given by the writer in a paper contributed to *Astronomy and Astro-Physics* of 1893 November. It was there noted that the precedence of small bright faculæ, in the order of time, was in favour of an uprush of heated gaseous matter, which, arriving at the higher elevations, radiated its light through a less depth of absorbing medium. The immediate result of this position of advantage for radiation would be the appearance of the bright lines of its constituents if they were not lost by projection upon the brilliant general spectrum of the solar light; but one of them escapes this obliteration owing to the dark background provided for it in the solar spectrum by the extensive absorption of calcium vapour,* and it is through the marks of this radiation on our photographic plates that we learn something of the history of these great luminous clouds. Their bright radiation shows where they are, but of itself leaves it uncertain whence they came. They must be above the reversing layer, and are certainly at a higher tem-

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* Recently Monsieur Deslandres has shown the existence of other constituents in the bright faculous matter, by some beautiful photographs of their forms over the solar surface, taken with his double-slit spectroscope directed on an apparently dark iron line. The writer had the privilege of examining one of these plates on the occasion of its author's visit to Stonyhurst in the summer, and saw that the photographic map of the faculous matter obtained by iron radiation was substantially the same as the map given by the calcium light.

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perature than their surroundings at their new elevation. They may have come up from below with the greater heat of a lower level, or they may have come from without and have been raised to a higher temperature by arrested motion. But they are at their highest elevation in the immediate vicinity of a spot, and lower at a distance from it; for close to a spot there is little or no double reversal, while away from it the central absorption is wide and strong—in other words, near a spot there is little or no superincumbent absorbing medium, while away from it there is much. For this reason it seems probable that the faculous clouds are thrown up from below, forming a rent in the solar atmosphere, where they leave a vast region of greatly reduced pressure and consequent chill, to account for the condensations which stop out the light from the photosphere and form the spot. They would attain their highest elevation directly over or near to the spot, and, drifting away, would gradually fall down. In the first days of its life the spot would be hidden from our sight by the bright faculæ directly over it; their nascent brightness would be enough to hide the spot in the telescope, and their partial continuous spectrum would mask its effect in the spectroscope. The spot would thus begin to appear as a dark speck in the midst of bright faculæ, and would grow to our vision as the faculous clouds uncover it falling down the slopes, like lava from a crater. This falling down is prettily shown on some of our plates by a V-shaped double reversal with the apex close to the spot band, and on others by a double V- or X-shaped reversal cut by the spot band through the centre. At the higher elevation the incandescent vapour is less dense and its radiation is narrower; falling, it becomes denser; its radiation is wider, but it is divided by greater central absorption.

Photographic Curves of Magnetic Variations, and their Connection with Solar Disturbances.—A comparison between terrestrial magnetism and solar surface disturbances, during the same period of least solar activity, shows a complete lack of agreement between them. With the charts of the solar surface, and the daily magnetic curves, to refer to, it was an easy task to pass in review the Earth's magnetic condition at every arrival of a group of spots and faculæ at the central meridian, or at the eastern or western limbs of the Sun. This was carefully done for three of the most disturbed regions, and the results were so contradictory of any supposable law that it was considered useless to continue the examination in this way. The converse method was then followed. A list of the greater magnetic disturbances furnished the dates for comparison with the sun-spot charts; and it was found that not only no condition, age, or position of spots or faculæ could be divined from the magnetic variations, but also that the greatest magnetic disturbance of the twelve months occurred at a time of complete and prolonged calm on both hemispheres of the solar surface. These magnetic perturbations

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began about 6 P.M. on November 26, lasting through the night, and were repeated the two following nights, beginning a little later each night. Our own evidence of the solar calm at this time is nearly complete, and shows that no spot appeared on the surface of the Sun between the middle of October and the middle of December; and the absolutely complete daily record of the solar surface given in the Greenwich volume of 1889 from observations at the Royal Observatory, and those of India and the Mauritius, show the same complete calm. It must, therefore, be considered certain that, whatever connection there may be between some sun-spots and our magnetic disturbances, the one is not the cause of the other, and there are causes of the one which do not affect the other. At present we can go no further than admit that there may be some common cause of both phenomena, and that at one time the Earth is more within its reach than the Sun; at another, the Sun is nearer to its influence than the Earth. This common cause may be some form of cosmical stuff crossing our planetary system. There might be times in our history when we encounter it in greater quantities, and these times might occur periodically. We should then have greater and more frequent solar disturbances, and greater and more frequent magnetic storms, but not necessarily synchronously. This periodicity seems to be true, for we find more magnetic disturbances at periods of greater solar activity.

We are in need of other evidence of the existence of this cosmical stuff, and herein is our weakness. If it exists, we are too near it to see it. Many of the cloud forms which grace our skies would vanish into apparent nothingness on a near approach to them. We are probably too near the Zodiacal light to make much of our observations of its behaviour, and so this cosmical stuff would, if it actually exists, elude our notice.

Stonyhurst College Observatory:
1894 *November.*

Photographs of the Nebulæ ♅ I. 84, h 1442, and ♅ II. 344 Comæ Berenicis. By Isaac Roberts, D.Sc., F.R.S.

The photograph of the nebulæ ♅ I. 84, *h* 1442, and ♅ II. 344 *Comæ Berenicis*, R.A. 12^{h} 45^{m}, Decl. north 26° $5'$, was taken with the 20-inch reflector on 1894 May 7, with exposure of the plate during 90 minutes, and the two copies now presented are enlarged, one to 1 millimetre to 24 seconds of arc, and the other to the scale of 1 millimetre to 6 seconds of arc.

The nebula ♅ I. 84 is No. 4725 in the *New General Catalogue*, and 3249 in the *General Catalogue*, where it is described by Sir J. Herschel as very bright; very large; extended; very suddenly very much brighter in the middle, with a bright nucleus.